RMRS Rocky Mountain Remediation Services, L.L.C.
. . . protecting the environment

PROCEDURE

DISCHARGE MEASUREMENT

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APPROVED FOR USE: [signature]
Manager, Surface Water

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1.0 PURPOSE AND SCOPE

This procedure describes procedures that will be used at the Rocky Flats Environmental Technology Site (RFETS) to measure surface water discharge in streams and ditches or from seeps and pipes. Discharge is defined as the volume rate of flow of water, including any substances suspended or dissolved in the water. This document outlines a set of standard methods for various flow conditions at RFETS.

This procedure describes equipment and procedures that will be used for field data collection and documentation in order to attain acceptable standards of accuracy, precision, comparability, representativeness, and completeness.

2.0 RESPONSIBILITIES AND QUALIFICATIONS

All personnel performing this procedure are required to have the appropriate health and safety training as specified in the site-specific *Health and Safety Plan*. Personnel obtaining surface water discharge measurements will be hydrologists, geologists, engineers or field technicians with an appropriate amount of applicable field experience or on-the-job training under the supervision of another qualified person.

3.0 REFERENCES

3.1 SOURCE REFERENCES

The following is a list of references reviewed prior to the writing of this procedure:

Driscoll, Fletcher G., Ph.D. Groundwater and Wells. Second edition. Johnson Filtration Systems, Inc., St. Paul, Minnesota. 1986.

Grant, Douglas M., and Brian D. Dawson, Isco Open Channel Flow Measurement Handbook, 4th ed., Isco, Inc., Lincoln, NE 1995.

Linsley, Ray K. and Joseph B. Franzini. Water-Resources Engineering. McGraw-Hill, Inc. 1964.

Rantz, S.E. et al. Measurement and Computation of Streamflow: Volume 1; Measurement of Stage and Discharge. Geological Survey Water-Supply Papers 2175. U.S. Government Printing Office. Washington, D.C. 1982.

Rouse, Hunter, ed. Engineering Hydraulics: Proceedings of the Fourth Hydraulics Conference. Iowa Institute of Hydraulic Research, June 12-15, 1949. John Wiley & Sons, Inc., New York.

U.S. Environmental Protection Agency. Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual. Environmental Services Division, Region IV. Athens, GA. April 1986.

U.S. Department of the Interior. Hydraulic Measurement and Computation: "Discharge Measurements at Gaging Stations." Book 1, Chapter 11, Geological Survey. Reston, VA. 1965.

U.S. Department of the Interior. National Handbook of Recommended Methods for Water-Data Acquisition. Office of Water Data Coordination, Geological Survey. Reston, VA, 1977.

3.2 INTERNAL REFERENCES

Related procedures cross-referenced by this procedure are:

- RMRS 1994, *Surface Water Data Collection Activities,* Rocky Flats Environmental Technology Site, February 23, 1994.

4.0 METHODS

This procedure describes Environmental Protection Agency (EPA)-approved discharge measurement methods. Methods are based on known conditions at RFETS. A variety of discharge measurement methods are required because flow conditions differ from site to site. In consideration of these varied conditions, this procedure describes possible flow conditions that may be encountered and describes methods that are to be used based on the site-specific flow conditions.

Because of the dynamic nature of surface water characteristics, flow measurement by the methods described in this document may be impossible at some sites. Selection of discharge measurement methods is based on the following existing conditions at RFETS:

- Flumes to be installed at RFETS include Parshall flumes, cutthroat flumes, H-flumes, and HS-flumes. Many stream channels are rocky and historical stream discharge measurements indicate that portable flumes failed to adequately contain flow.
- Pipes in and around the Industrial Area (IA) contain gravity flow (These may be difficult to reach with a velocity measuring device). Pipe flows may be measured by weir inserts, area-velocity meters, or submerged probe flow meters.
- Weirs installed at the Site include sharp-crested v-notch weirs and rectangular weirs.

In view of these existing physical constraints, Table 4-1, Discharge Measurement Methods Based on the Type of Site, should be consulted to select the method used at a particular site.

A control structure (flume or weir) method should be used for discharge measurements in streams or ditches when they are operational. The volumetric method, is to be used only for measurement of very low flow (i.e. less than 0.1 cubic feet per second (cfs)) or where flows are not channeled but may be collected volumetrically.

Table 4-1 Discharge Measurement Methods Based On The Type Of Site

Type of Site	Method
Pipe	Volumetric, Area-Velocity Meter, Submerged Probe Meter
Stream or Ditch	Flume or Weir
Channel with No Flume or Weir	Velocity-area
NPDES discharge locations	Flume or Weir with Totalizer

4.1 BUCKET AND STOPWATCH VOLUMETRIC METHOD

The volumetric method is a simple and accurate method for measuring flow from small discharges and will be utilized at RFETS to measure gravity flow discharges. This method involves observing the time required to fill a container of known capacity, or the time required to partly fill a calibrated container to a known volume. Alternatively, in the case of measuring discharge remotely in a sump or standpipe setting, the volumetric method may be performed by capturing flow in a container for a set period of time: no less than 10 seconds. This volume of water is then measured and discharge is determined.

4.1.1 Equipment

The "bucket and stopwatch" technique is particularly useful for the measurement of small flows. Equipment required to make this measurement is a calibrated container and a stopwatch. For measurements at RFETS, calibrated containers of varying sizes will include:

- 5-gallon calibrated bucket
- 2-liter graduated cylinder
- 1-liter graduated cylinder
- 1-liter beaker
- 500-milliliter beaker
- 250-milliliter beaker

Extension rods will be used to hold a container for capturing flow in enclosed areas containing discharging pipes.

4.1.2 Maintenance and Calibration Procedures

Graduated cylinders are incremented in terms of milliliters which can be easily converted to gallons. The incremental volume of a 5-gallon bucket can be determined by adding known volumes of water and recording the depth after each addition.

4.1.3 Field Procedures

In accordance with *Surface Water Data Collection Activities* (RMRS 1994), the field crew will assess the type of site being visited. Upon arrival at the site, the technicians will evaluate the flow conditions to select the appropriate method for flow measurement. If the flow conditions meet those outlined in Subsection 5.1.1., then the technicians will observe and use judgment in approximating the flow volume and will select an appropriately sized volumetric container to use the volumetric method of flow measurement.

A technician will use a stopwatch to measure the time required to fill a volumetric container. The technician will time flow into the container for a minimum of 10 seconds. Three consecutive measurements will be made and noted, and the results averaged to determine the discharge.

If remote measurement is necessary, a container will be attached to an extension rod. The technician will time flow for a minimum of 10 seconds. The volume of water will then be poured into a calibrated container, measured, and recorded. Three such measurements will be made, noted, and the results averaged to determine the discharge.

4.1.4 Discharge Calculations

Discharge will be determined initially in gallons per second (gal/s) or in milliliters per second (ml/s). These values will be noted, but the averaged value will be reported in cubic feet per second (cfs). Calculations will be performed as follows:

- Record each of the three measurements in terms of gallons per second or milliliters per second, depending on the volumetric container.
- If one of the three measurements is 50 percent or more different from the other two measurements, then this value will not be used. Instead, three additional measurements will be taken and, provided that none of these measurements differs by greater than 50 percent from the other two measurements, these values will be used.
- Average the three values.
- Convert the averaged value to cfs as follows:
  - to convert ml/s to cfs, multiply by 3.53×10^{-5}
  - to convert gal/s to cfs, multiply by 0.134
- Record discharge in cubic feet per second (cfs).

4.2 VELOCITY-AREA METHOD

The vertical axis current meter has been selected to perform velocity-area method discharge measurements. A common type of vertical axis current meter is the Price meter, type AA (see **Figure** 4-1). A current meter is an instrument used to measure the velocity of flowing water. The principle of operation is based on the proportionality between the velocity of the water and the resulting angular velocity of the meter rotor. By placing a current meter at a point in a stream and counting the number of revolutions of the rotor during a measured interval of time, the velocity of water at that point is determined. The number of revolutions of the rotor is obtained by an electrical circuit through the contact chamber. Contact points in the chamber are designed to complete an electrical circuit at selected frequencies of revolution. The electrical impulse produces an audible click in a headphone. The intervals during which meter revolutions are counted are timed with a stopwatch.

A Price pygmy meter will be used in shallow depths and low velocities (see Figure 4-1). The pygmy meter is scaled two-fifths as large as the type AA meter. The pygmy meter makes one contact (click) per revolution while the type AA meter can make one click per revolution or one click per five revolutions. The predominant flow conditions in channeled streams at RFETS indicate that the pygmy meter will be used more frequently than the Price AA meter.

4.2.1 Introduction

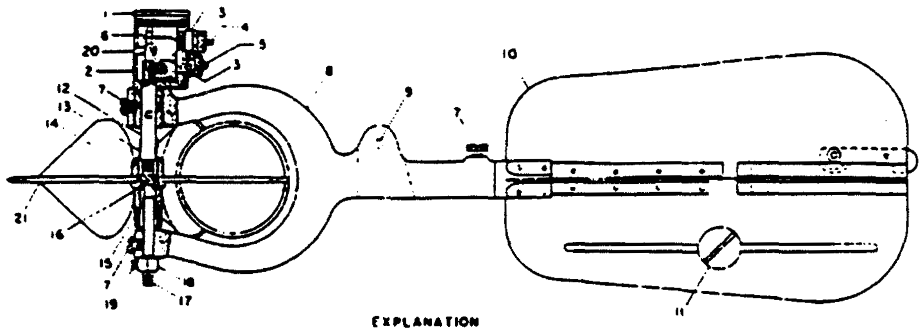
The current meter measures velocity at a point. The velocity-area method requires measurement of the mean velocity in selected subsections of the stream cross-section. By dividing the stream width into subsections, discharge becomes the total of discharges measured in each subsection (see Figure 4-2). Velocity (v) is measured at each subsection, and discharge becomes the sum of the products of each point velocity and cross-sectional area of each subsection:

$$\mathbf{Q = \Sigma va}$$

Where **Q** is total discharge, **v** is point velocity, and **a** is the area of the subsection.

In general, the hydrographer measuring discharge should strive to measure no more than 5% of the flow in any one subsection. However, for small streams this is often impossible. Therefore, the hydrographer should divide the channel cross-section into as many subsections as possible and make two (2) complete discharge measurements using different sections for each. Further, subsections need not be of identical width.

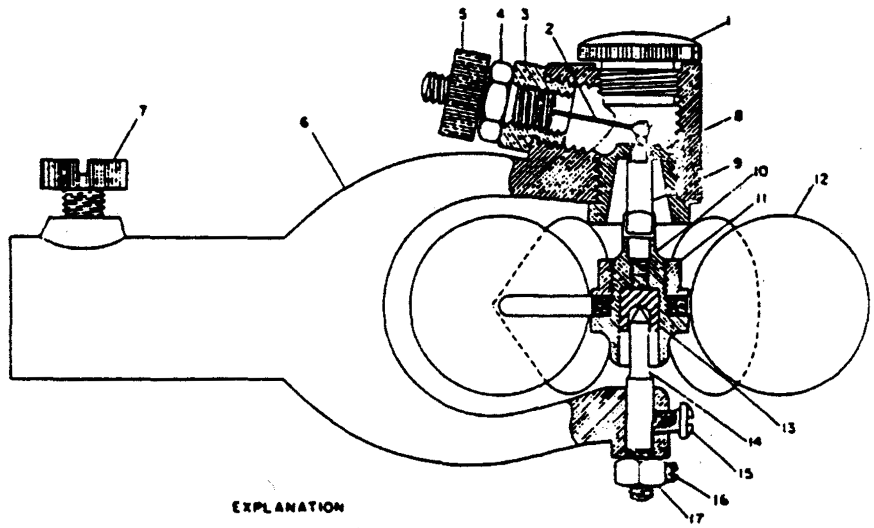
Velocities near banks are generally lower than velocities near the center of streams, thus these subsections may be wider than subsections near the center. Subsections will also be more closely spaced if a stream has an unusually deep portion in the cross-section, or if velocities are higher than usual for the cross-section. The minimum section width for the AA-meter is 0.40 feet and the minimum section width for the pygmy meter is 0.30 feet.



EXPLANATION

1. Cap for contact chamber
2. Contact chamber
3. Insulating bushing for contact binding post
4. Single-contact binding post
5. Penta-contact binding post
6. Penta gear
7. Set screw
8. Yoke
9. Hole for hanger screw
10. Tailpiece
11. Balance weight
12. Shaft
13. Bucket-wheel hub
14. Bucket-wheel hub nut
15. Raising nut
16. Pivot bearing
17. Pivot
18. Pivot-adjusting nut
19. Keeper screw for pivot-adjusting nut
20. Bearing lug
21. Bucket wheel

Assembly diagram of type-AA Price current meter.



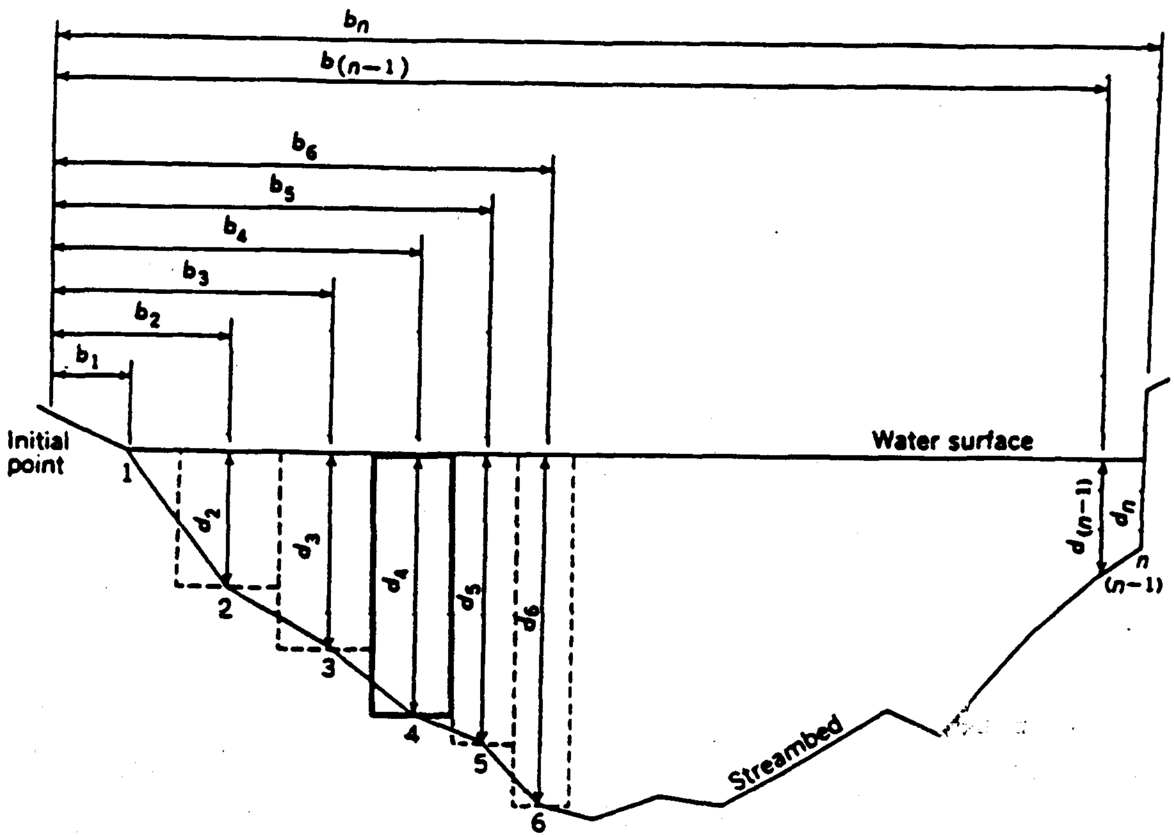
EXPLANATION

1. Cap for contact chamber
2. Binding-post beaded wire
3. Binding-post insulating bushing
4. Binding-post body
5. Binding-post nut
6. Yoke
7. Yoke set screw
8. Upper bearing
9. Shaft
10. Bucket-wheel hub
11. Bucket-wheel hub nut
12. Bucket wheel
13. Pivot bearing
14. Pivot
15. Pivot set screw
16. Pivot-adjusting nut keeper screw
17. Pivot-adjusting nut

Assembly diagram of pygmy current meter.

Price Type AA Meter, Top;
Price Pygmy Meter, Bottom

FIGURE 4-1



EXPLANATION

1, 2, 3 ....n	Observation verticals
$b_1, b_2, b_3, \ldots. b_n$	Distance, in feet or meters, from the initial point to the observation vertical
$d_1, d_2, d_3, \ldots. d_n$	Depth of water, in feet or meters, at the observation vertical
Dashed lines	Boundaries of subsections; one heavily outlined is discussed in text

Definition Sketch of Midsection
Method of Computing Cross-Section

FIGURE 4-2

Typically, velocities will be measured by current meter for a 40-70 second period. It is recognized that 40 to 70 seconds is not long enough to ensure the accuracy of a single point-observation of velocity. However, because pulsations caused by turbulent and eddying effects are random and because velocity observations during a discharge measurement are made at several verticals, there is little likelihood that the pulsations will bias the total measured discharge of a stream. Longer periods of current meter observation at a point are not used because (1) it is desirable to complete a discharge measurement before the stage changes significantly and, (2) the use of longer observation periods may add significantly to the operating cost of data collection.

4.2.2 Required Measurement Conditions

In order to make a velocity-area discharge measurement, the following conditions are required:

1. The stream must be channeled; that is, banks must channel the stream flow.
2. Depth must be greater than 0.2 foot across most of the cross-section being measured.

The ideal channel cross-section is trapezoidal in shape, completely smooth in boundary materials, and possesses a uniform velocity distribution. It is recognized that no such cross-sectional areas exist at RFETS. Therefore, minor modifications to the stream channels will be used in order to optimize measurement conditions. These modifications may include removal of aquatic vegetation, ice, and moving small stones which impact velocity upstream or downstream of the cross-section.

Current meter measurements will be made by wading, if conditions permit. The type AA or pygmy meter is used for wading measurements. Table 4-2 lists the type of meter and velocity method to be used for wading measurements at various depths. The hydrographer should stand at arm's length to the side of the meter.

Table 4-2 Velocity Measuring Point Selection

Stream Depth (ft)	Type of Meter	Velocity Measuring Point(s) (% of Depth)
2.5 or more	Type AA	0.2 and 0.8
1.5 - 2.5	Optional	0.6
0.3 - 1.5	Optional	0.6
< 0.3	Pygmy	0.5

Some departure from Table 4-2 will be permitted. If the stream velocity is high it may not be possible to count clicks with a pygmy meter. If this occurs the type AA meter should be used. Do not switch from one meter to another in the middle of a discharge measurement.

Under open channel laminar flow conditions, the effect of fluid contact with the bed of a stream channel and the air is a vertical distribution of velocities. Consistent with this velocity distribution, actual observation and mathematical theory has demonstrated that a single measurement of velocity taken at 0.6-depth or the average of two point velocities taken at 0.2 and 0.8 of the depth below the surface accurately results in mean velocity in the vertical (U.S.G.S. Water-Supply Paper 2175,133-134pp).

If the stream is generally less than 2.5 feet deep, use the six-tenths (0.6) method. If the stream is generally greater than 2.5 feet, the two-and-eight-tenths (0.2 and 0.8) method, also known as the two-point method, will be used. A complete discussion concerning how to set the wading rod to place the current meter at proper depths is contained in Subsection 4.2.3.1.

In the 0.6-depth method, an observation of velocity made in the vertical at 0.6 of the depth below the surface is used as the mean velocity in the vertical. In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the surface. The average of the two observations is taken as the mean velocity in the vertical.

A depth of 1.25 feet will accommodate the 0.6-depth method without causing the meter to be set closer than 0.5 feet from the stream bed; if the meter is set any closer to the stream bed, it will under-register the velocity. If the technician is at a measurement section that has only a few verticals shallower than 1.25 feet, the technician should use the type AA meter rather than the pygmy meter if the depth is no less than 0.5 feet at any vertical.

Vertical axis current meters do not register velocities accurately when placed close to a vertical wall. A Price meter held close to a right-bank vertical wall will under-register because the slower water velocity near the wall strikes the effective (concave) face of the cups. The converse is true at a left-bank vertical wall. (The terms "left bank" and "right bank" designate direction from the center of a stream for an observer facing downstream.) The Price meter also under-registers when positioned close to the water surface or close to the stream bed.

4.2.3 Equipment

Current meters, timers, depth and width measuring devices, and a means of counting meter revolutions are needed for measurement of discharge. The equipment includes:

- Top-setting wading rod and Current meter
- Width-measuring devices, either engineer's tape or tagline
- Digital counter or headset and stopwatch
- Current meter rating tables
- Stakes for width-measuring devices
- Calculator

4.2.3.1 Top-setting Wading Rod

The depth-measuring device that will be used is the wading rod. The current meter is attached to the wading rod. The top-setting rod is preferred for use at RFETS because of the convenience in setting the meter at the proper depth and because the hydrographer's hands remain dry in the process. The top-setting wading rod has a 1/2-inch hexagonal main rod for measuring depth and a 3/8-inch diameter round rod for setting the position of the current meter.

4.2.3.2 Current Meter

See description in Subsection 4.2.1.

4.2.3.3 Engineer's Tape or Tagline

Tape measures or pre-marked taglines are used for stream width measurements. Orientation normal to the flow pattern of the stream and elimination of most of the sag, through support or tension, are recommended for improved accuracy.

4.2.3.4 Digital Revolution Counter or Headset

The digital revolution counter attaches to an electronic connection at the top of the wading rod. The digital display shows the number of seconds of elapsed time. The hydrographer stops the counter after 40 or more seconds, and the counter automatically displays the velocity.

If the digital counters are unavailable, the headset will be used as a means for determining the number of revolutions. A headset attaches to an electronic connection at the upper end of the wading rod. The hydrographer wears this headset to listen to the audible clicking sounds produced by current meter revolutions. The number of rotations are counted and timed. Velocities as a function of time are listed on a current meter rating chart, which is kept in the current-meter carrying case.

4.2.3.5 Stopwatch

A stopwatch is used to measure time during which velocity is measured at each point in the cross-section.

4.2.4 Maintenance and Calibration Procedures

Prior to and following the use of the current meter, spin tests will be conducted to ensure that the unit performs acceptably. The spin test will be performed in an enclosed area, such as in the cab or in the enclosed rear of a truck, to prevent wind interference. The test is to be performed prior to attaching the current meter to the wading rod. While holding the meter steady in an area sheltered from breezes, the technicians will spin the rotor and then press the start button on the stopwatch. The technician will observe the meter until the rotor ceases to spin.

The duration of the spin for the pygmy meter will be more than 40 seconds, and for the Price AA meter, it will be more than 90 seconds. If the meter fails to meet the time-of-spin criteria, the meter will be cleaned and oiled before use. If the meter continues to spin well beyond these time limits, the record will indicate that the meter spun for 40+ seconds, in the case of the pygmy meter, or for 90+ seconds in the case of the Price AA meter.

To ensure reliable observations of velocity, it is necessary that the current meter be kept in good condition. Before and after each discharge measurement, the meter cups or vanes, pivot and bearing, and shaft will be examined for damage, wear, or faulty alignment. During measurements, the meter will be observed periodically when it is out of the water to be sure that the rotor spins freely.

Meters will be cleaned and oiled daily when in use. If measurements are made in sediment-laden water, the meter will be cleaned immediately after each measurement. After oiling, wipe away any excess oil and spin the rotor to make sure that it operates freely. If the rotor stops abruptly, the cause of the trouble will be sought and corrected before using the meter.

In addition to meter maintenance, the entire unit consisting of current meter, wading rod, and digital counter or headset will be checked before departure to the field each day as follows:

- Attach the current meter and digital counter/headset to the wading rod.
- Check the digital counter by ensuring that the readout is visible when the unit is turned on.
- If a headset is being used:
  - Spin the current meter to ensure that audible clicks occur.
  - If audible clicks do not occur, the following steps should be taken:
    - Check that electronic connections are tight.
    - Check that the cat's whisker lightly contacts the upper part of the shaft.
  - Spin again. If audible clicks still do not occur, check that the battery in the headset is properly aligned. Replace the battery, if necessary.

4.2.5 Field Procedures

4.2.5.1 Overview

In accordance with, *Surface Water Data Collection Activities* (RMRS 1994), the field crew will determine the type of site being visited. Upon arrival at the site, the field technicians will evaluate the flow conditions to determine which measurement method is appropriate. Based on flow conditions, either the Price AA meter or the pygmy meter will be selected to perform a velocity-area measurement.

At each measurement point (or section) across the stream cross-section, depth is measured prior to measurement of velocity. Place the wading rod about 0.5 feet downstream from the tagline to prevent contact with the current meter when the meter is lowered into measuring position. Place the wading rod in the stream so the base plate rests on the stream bed. The depth of water is read from the graduated main rod. The main rod is graduated into 0.1-foot increments. These increments are indicated by a single score in the metal. Half-foot increments are marked by two scores in the metal, and each foot is marked by three scores in the metal. A vernier scale on the upper handle of the rod corresponds to 0.1-foot increments, and has 1 through 9 in raised numbers next to raised marks. A sliding, adjustable rod, known as the setting rod, to which the meter is attached, has single scored marks which are aligned with values on the vernier scale.

In high velocity areas, it is recommended that depth be read as the value between depth on the upstream side of the rod and depth on the downstream side of the rod. Depth is measured to the nearest 0.02 foot. This depth is used to set the vertical location of the current meter.

The setting rod is then adjusted downward so that the scored mark of the setting rod which corresponds to the range of depth in feet (e.g., if depth = 0.46, range in feet = 0; or if depth = 1.72, range in feet = 1) is aligned with the stream depth value transposed to the vernier scale. This automatically positions the meter for use in the 0.6 method as the meter is then six-tenths of the total depth from the surface of the water.

For using the two-point method of velocity measurement, the depth of water is divided by 2. This value is set so that the meter will be at the 0.8-depth position from the water surface. The depth of water is then multiplied by 2, and this value is set. The meter will then be at the 0.2-depth position measured down from the water surface. These two positions represent the conventional 0.2- and 0.8-depth positions. If depths are less than 0.30 foot, the 0.5 method may be used. The observation depth recorded will then be 0.5 of the total depth.

4.2.5.2 Steps to be Followed in Measuring Discharge.

If water quality or sediments are sampled in conjunction with discharge measurement, samples will be collected prior to making discharge measurements. The following steps are to be followed in discharge measurement:

- Evaluate the measurement location. Chose a location where flow is least turbulent. If the prescribed location is in a stream reach with highly turbulent flow conditions, try to select a location immediately upstream or downstream from the prescribed location. Flow should be visible from bank to bank. Eddies and slack water must not be present. Neither the type AA meter nor the pygmy meter will be used for measuring velocities slower than 0.1 fps unless absolutely necessary.
- Remove aquatic vegetation, ice, or other minor flow impediments. When such modifications are made, exercise great care to avoid unnecessary movement of sediments or the splashing of sediments or water onto field personnel. Allow flow to stabilize before the current meter measurement begins.
- Position a tape about 1 foot above the surface of the water. Secure the tape so that it remains taut and perpendicular to the channel.

- Select a starting point at either the left bank (left edge of water, LEW) or the right bank (right edge of water, REW). LEW and REW are determined when facing downstream. Record LEW and REW in the manner shown in Figure 4-3 on the Discharge Measurement Notes (Figure 4-4).
- Note the distance in feet, and the stream direction, that this cross-section lies from the prescribed location. For example, the note may read "25 feet downstream" or "15 feet upstream."
- Measure the width of the stream, in feet. After selecting the Price AA or pygmy meter (see Table 4-2), follow guidelines in Subsection 4.2.2 to select the number of subsections in which to measure velocity attempting to measure no more than 5% of total flow in any one section, if possible.
- After determining the distance desired between measuring points, commonly referred to as sections, measurement can begin. Record the time and bank at which measurement starts on the discharge measurement notes as "REW Start 0000", using REW or LEW depending upon whether starting at the right or the left edge of the water.
- Note the distance to the beginning edge of water from the initial point. The initial point is an arbitrary point on the tape, preferably zero, which lies on the shore of the stream. All station locations are recorded as distances from the initial point.
- Proceed to the first station beyond the edge of water. Record the distance from the initial point on the discharge measurement notes. Place the wading rod into the stream so the base plate rests on the stream bed.
- Stand downstream of the tagline or tape and face upstream. Do not stand behind or close to the meter. Raise the current meter on the wading rod so that it is well above the surface of the water.
- Measure stream depth at the measurement point as indicated on the wading rod. Record the stream depth to the nearest 0.02 foot (for example 0.32 feet or 1.54 feet).

DISCHARGE MEASUREMENT NOTES

Party: GCA, MAS Comp. By: MAS Checked By: GCA

Width: [illegible] Area: 0.698 ft² Gage Height:

Method: [illegible] Type of Meter: Pygmy Spin: Before 40+ After 40+

Comments/observations:

Cross Section

Flow

Other

	DIST FROM INIT POINT	WIDTH (FT)	DEPTH (FT)	OBSER DEPTH	REVS	TIME (SEC)	VELOCITY (F/S) AT POINT	VELOCITY (F/S) MEAN IN VERTICAL	AREA (FT²)	DIS-CHARGE (CFS)
LEW	5.0	0.1	∅		—	—			∅	
	4.8	0.3	0.2		15	43	0.369		0.06	0.022
	4.4	0.4	[illegible]		3	70	0.07		0.152	0.011
	4.0	0.4	0.32		0	—	—		0.128	—
	3.6	0.4	0.36		10	44	0.25		0.144	0.036
	3.2	0.4	0.36		7	52	0.16		0.144	0.023
	2.8	0.35	0.20		∅	—	—		0.07	—
REW	2.5	0.15	∅		—	—	—		∅	—
									0.698	0.092cfs

Total Discharge [illegible]

Site ID SW∅∅5 Date 5/1/90 Signature M. [illegible]

Computation Notes of a Current-Meter Measurement

FIGURE 4-3

Meas. No. ....

Comp. by ....

DISCHARGE MEASUREMENT NOTES

Checked by ....

Sta. No. ....

....

Date .... 19...... Party ....

Width .... Area .... Vel. .... C. H. .... Disch. ....

Method .... No. secs. .... G. H. change .... in .... hrs. Susp. ....

Method coef. .... Hor. angle coef. .... Susp. coef. .... Meter No. ....

GAGE READINGS				
Time		Recorder	Inside	Outside
Weighted M. G. H.				
G. H. correction				
Correct M. G. H.				

Type of meter ....

Date rated .... for rod, other.

Meter .... ft. above bottom of weight.

Spin before meas. .... after ....

Meas. plots .... % diff. from rating ....

Wading, cable, ice, boat, upstr., downstr., side bridge .... feet, mile, above, below gage, and ....

Check-bar, found ....

changed to .... at ....

Correct ....

Levels obtained ....

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section ....

Flow .... Weather ....

Other .... Air ....°F@ ......

Gage .... Water ....°F@ ......

.... Record removed .... Intake flushed ....

Observer ....

....

Control ....

....

Remarks ....

....

....

G. H. of zero flow .... ft.

.0 .10 .20 .30 .40 .50 .60 .70 .75

Flow at—

[illegible]	Dist. from initial point	Width	Depth	[illegible]	Revolutions	Time in seconds	VELOCITY At point	VELOCITY Mean in vertical	Adjusted for hor. angle or	Area	Discharge

.80 .85 .90 .92 .94 .96 .97 .98 .99 1.00 .99 .98 .97 .96 .94 .92 .90 .85 .80

.0 .10 .20 .30 .40 .50 .60 .70 .75

Discharge Measurement Notes

FIGURE 4-4

- Lower the meter to the required depth and record the observation depth. The observation depth as a fraction of total depth is 0.6, 0.2, 0.8 or occasionally 0.5.
- The technician will stand in a position that least affects the velocity of the water passing the current meter. That position is usually obtained by facing upstream with the arm fully extended. The technician will stand at about a 45-degree angle downstream from the wading rod. The wading rod is held in a vertical position with the meter parallel to the direction of flow. Avoid standing in the water when possible.
- Start the digital counter. After 40 seconds, stop the counter. Note that the counter reports velocity.
- If using the headset rather than the digital counter, start the stopwatch on the first click and begin counting clicks. The first click counted after starting the stopwatch is counted as one.
- After at least 40 seconds have passed, stop the stopwatch on a click. Record the number of seconds and the number of revolutions (clicks) on the same line of the notes as the recorded depth.
- Determine velocity as a function of elapsed time and number of revolutions from the velocity chart. Record velocity in the appropriate column. If the flow meter is not lined up parallel to the flow, the cosine of the angle that the flow direction is from parallel is needed to correct velocity values. This is done by the following:
  - Hold up a copy of the discharge notes.
  - Line up the dot (shown in the cosine of the angle column of the notes) with the number on the tape that designates the measurement point of the cross-section.
  - Rotate the note by pivoting at the dot until the edge of the note is aligned with the flow. Find the number along the notes perimeter that lines up with the tape. This is the cosine of the angle. Record this value for the station.
- Proceed to the next station. Record the distance from the initial point to the station. Repeat measurements of depth and velocity. Continue in this manner across the stream.
- After recording the distance measurement at the last station, record the time at which the ending edge of water is reached (e.g. LEW [or REW] FINISH 1330).
- Note velocity and depth at the edge of water as zero.
- Evaluate and record the following: Flow characteristics, weather conditions, air temperature, water temperature, observer(s), type of meter, and remarks.

- If less than 20 subsections have been used for the measurement, repeat the measurement steps. Begin from the opposite bank from where the previous measurement began.

4.2.6 Discharge Calculations

Using a calculator as needed, calculate discharge on the discharge notes as follows:

- Use the distances from initial point to compute width for each subsection. The first width is computed by subtracting the first distance (edge of water) from the second distance, and dividing this quantity by two. The second width will be the difference between the third distance and the first distance, divided by two. For each subsequent width, subtract the previous station distance from the following station distance, and divide this quantity by two. The final width is calculated as the difference between the final distance and the second-to-the-last distance, divided by two. Sum the width column and check to be sure that the calculated width equals the distance between the REW and LEW.
- Multiply the width by the depth for each station to determine the area of each subsection. Sum the areas to determine total area.
- If the angle between the flow and the meter orientation is not 90 degrees, correct the measured velocity readings by multiplying the velocity by the cosine of the angle.
- Multiply the velocity by the area for each station to obtain the discharge for each subsection.
- Sum the discharges for each subsection to determine total discharge and record the value.
- If two sets of discharge measurements beginning at opposite banks were taken, repeat the discharge calculations for the second set of data. Average the total discharges for the two measurements. Record the average value and report it for input into the database.

4.3 CONTROL STRUCTURES

Control structures such as weirs and flumes are most commonly used at the Site to determine discharge. These structures have regular dimensions that allow for a consistent relationship between stage (water level) and discharge that is represented by a mathematical equation called the "theoretical rating" for the structure.

4.3.1 Introduction

4.3.1.1 Weirs

Weirs are classified under the general categories of (1) broad-crested, or (2) sharp-crested. Discharge over a broad-crested weir is represented by the rating equation below.

$$Q=CLH^{3/2},$$

where **Q** is the discharge, **L** is the crest length, and **H** is the depth of water over the crest of the weir. Values for the coefficient **C** are given in hydraulic handbooks. While the exponent for **H** listed here is applicable to many weirs, hydraulic handbooks should be consulted to find the correct exponent for the weir being used.

Sharp-crested weirs are constructed in a variety of shapes, but the most common are V-notch, rectangular, and Cipolletti. The stage-discharge rating for a v-notch weir is:

$$Q=CH^{2.5},$$

and the stage-discharge rating for a rectangular weir is:

$$Q=C \times (L-0.2 \times H) \times H^{3/2}.$$

Values for **C** for v-notch and rectangular weirs are found in hydraulic and open channel flow handbooks (see references).

4.3.1.2 Flumes

A calibrated constriction placed in a stream channel changes the level of the water in or near the constriction. Flumes are constructed so that a restriction in the channel causes the water to accelerate, producing a corresponding change (drop) in the water level.

When the physical dimensions of the flume constriction are known, discharge through the constriction may be determined from measurement of depth. Refer to Subsection 4.3.6.2 for a description of discharge measurement for Parshall flumes.

Typical flumes consist of three sections:

- A converging section to accelerate the approaching flow.
- A throat section, whose width is used to designate flume size.
- A diverging section, designed to ensure that the level downstream is lower than the level in the converging section.

The stage of a stream is the height of the water surface above an established elevation. Stage is usually expressed in feet. The Parshall flume consists of a converging section with a level floor, a throat section with a downward sloping floor, and a diverging section with an upward sloping floor (see Figure 4-5). The principal feature of the Parshall flume (developed by R. Parshall in 1922) is an approach reach having converging side walls and a level floor, the downstream end of which is a critical depth cross-section. The primary stage measurement is made in the approach reach at some standard distance upstream from the critical-depth cross-section. The flumes are designated by the width (w) of the throat.

Cutthroat flumes have been used extensively at the Site for stream flow gain and loss studies to investigate surface-water/groundwater interactions and to measure stormwater runoff in small drainages (1 acre or so). The cutthroat flume resembles the Parshall flume, but there is no parallel wall throat section, which is how it derives its name. The cutthroat flume also has a flat bottom and relies on free fall flow over the downstream end of the flume to create hydraulic conditions required to use the theoretical rating equation. If such conditions do not exist, the flumes is "submerged," requiring stage measurement at both the upstream and downstream ends of the flume and use of special rating equations. Therefore, free flow conditions are preferred. The following rating may be used for free flow conditions for cutthroat flumes. Submerged flow ratings are available in handbooks listed in the references.

$$Q= K\,W^{1.025}\,H^{n1}.$$

In this equation, **K** is the free flow coefficient, **W** is the throat width, and **n1** is the free flow exponent. In most cases, flumes are calibrated and come with standard ratings from the manufacturer.

4.3.2 Required Measurement Conditions

4.3.2.1 Weirs

For weir formulas to give accurate values of discharge, the upstream face of the weir must be vertical and at right angles to the channel, and the crest of the weir must be horizontal. In addition, atmospheric pressure should be maintained under the nappe, and the approach channel should be straight and unobstructed. The head, **h**, should be measured 4.5 times the expected maximum stage upstream from the weir to avoid the affect of curvature of the water surface near the weir. For example, if the expected maximum stage on the weir is one foot, then the staff gage should be installed 4.5 feet upstream from the weir.

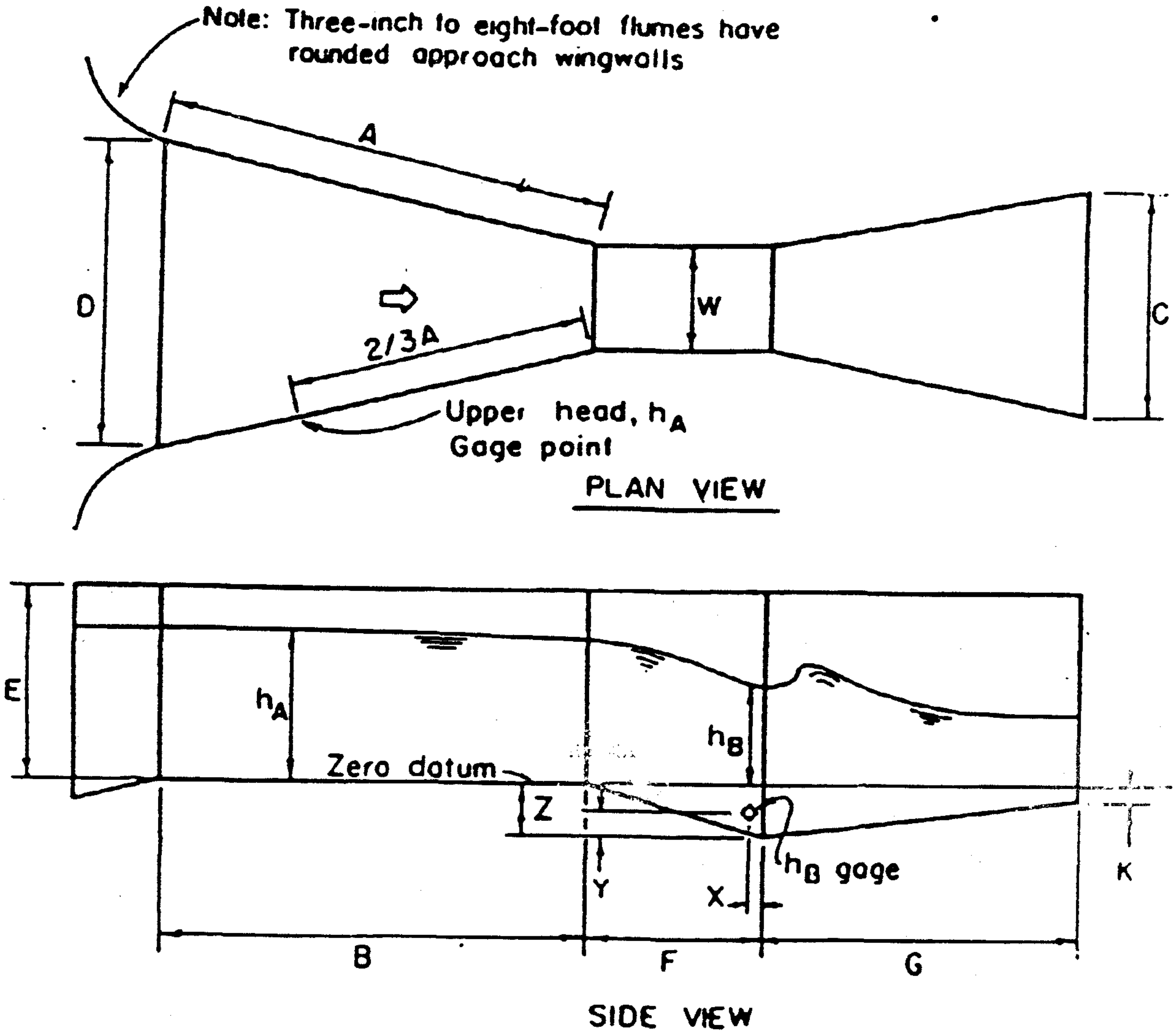
4.3.2.2 Flumes

Ideally, flow rate through a flume may be determined by measurements at a single point some distance downstream from the inlet and above the throat. For Parshall flumes, the stage is measured two-thirds the distance from the throat in the converging section. For cutthroat flumes, the stage is measured two-ninths the distance from the throat in the converging section. Type-H and HS flumes have stage measurement points at 1.25 times the maximum depth of the flume from the end of the flume's nozzle (i.e. downstream end).

4.3.3 Equipment

The following equipment are needed for inspection of flumes.

- Current meter
- Carpenter's level
- Framing square
- Measuring tapes
- Staff gauge



FROM: U.S.E.P.A. ENGINEERING SUPPORT BRANCH STANDARD OPERATING PROCEDURES AND QUALITY ASSURANCE MANUAL

Configuration and Descriptive Nomenclature for Parshall Flumes

FIGURE 4-5

4.3.4 Maintenance and Calibration Procedures

4.3.4.1 Weirs

All weirs will be inspected to determine that they provide a uniform influent flow distribution and that they are placed squarely across the channel. Corrosion of the crest of a sharp-edged weir or damage by floating debris may alter the weir coefficient. If a broad-crested weir is to be used for measurement purposes, its shape must conform to one for which coefficients have been established by testing. The equations and tables found in hydraulics references that are used to compute the flow over weirs apply only to free-flow conditions. When the water level downstream from a weir rises above the level of the weir crest, the weir crest is said to be submerged. Formulas have been developed for flow over submerged weirs, but under such conditions accurate flow measurements are estimated because surface disturbances downstream from the weir make it difficult to measure the depth of submergence.

4.3.4.2 Flumes

All flumes will be inspected to determine that entrance conditions provide a uniform influent flow distribution, the converging throat section is level, and that the throat section walls are vertical. The flume will be closely examined to determine that it is discharging freely. Any problems observed during the inspection will be noted and reported to the field manager.

4.3.5 Procedures

4.3.5.1 Overview

In accordance with *Surface Water Data Collection Activities* (RMRS 1994), the field crew will determine possible flow conditions based on past activities at the Site before going to the field data site. Upon arrival at the Site, the technicians will evaluate the flow conditions to verify the appropriate method for flow measurement. If the flow conditions meet those outline in Subsection 5.1.3.2, then the technicians will observe and use judgement in approximating the flow volume and will perform a measurement based on use of the control structure.

4.3.5.2 Steps to be Followed in Measuring Discharge

- Remove any material that may have accumulated in the flume or on the weir.
- If the station includes a recorder, inspect the strip chart and/or LCD readout on the recorder to verify that it is operating.
- Note any deterioration of the station; report these conditions to the field manager at the conclusion of daily data collection activities.
- Measure and record the throat width to the nearest 1/10 of an inch.
- Use the staff gage to measure and record the gage height to the nearest 0.005 foot, and record the corresponding recorder reading for the same time of day.
- Calculate discharge as described in Subsection 4.2.6.
- Record the calculated discharge and the time and date of the site visit.

4.3.6 Discharge Calculations

4.3.6.1 Weirs

Equations are derived for weirs of specific geometry which relate static head to discharge. Weirs are generally classified into two general categories: (1) broad-crested, and (2) sharp-crested. A set of weir tables is necessary for calculating flows. The weir tables are specific to the type of weir.

4.3.6.2 Flumes

A set of flume tables is necessary for calculating flows. The flume tables are specific to the type of flume. For Parshall Flumes refer to Table 4-3, Free-Flow Discharge-Parshall Flume, cfs. Based on the gage height (head, **H**, in feet) and the throat width of the flume (size of flume, **W**), the discharge is read directly from Table 4-3.

Note that approximate values of discharge for heads other than those shown may be found by direct interpolation in the table.

5.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance (QA) and quality control (QC) activities will be accomplished according to applicable project plans as well as quality requirements in this procedure.

Table 4-3

Free Flow Discharge - Parshall Flume, cfs

Head, H_a (feet)	Size of Flume, H										
	3"	6"	9"	1'0"	1'6"	2'0"	3'0"	4'0"	5'0"	6'0"	7'0"	8'0"
0.1	0.028	0.05	0.09	-	-	-	-	-	-	-	-	-
0.2	0.082	0.16	0.26	0.35	0.51	0.66	0.97	1.26	-	-	-	-
0.3	0.154	0.31	0.49	0.64	0.94	1.24	1.82	2.39	2.96	3.52	4.08	4.62
0.4	0.241	0.48	0.76	0.99	1.47	1.93	2.86	3.77	4.68	5.57	6.46	7.34
0.5	0.339	0.69	1.06	1.39	2.06	2.73	4.05	5.36	6.66	7.94	9.23	10.51
0.6	0.450	0.92	1.40	1.84	2.73	3.62	5.39	7.15	8.89	10.63	12.36	14.08
0.7	0.571	1.17	1.78	2.33	3.46	4.60	6.86	9.11	11.36	13.59	15.82	18.04
0.8	0.702	1.45	2.18	2.85	4.26	5.66	8.46	11.25	14.04	16.81	19.59	22.36
0.9	0.843	1.74	2.61	3.41	5.10	6.80	10.17	13.55	16.92	20.29	23.66	27.02
1.0	0.992	2.06	3.07	4.00	6.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00
1.1	-	2.40	3.55	4.62	6.95	9.27	13.93	18.60	23.26	27.94	32.62	37.30
1.2	-	2.7[illegible]	4.06	5.28	7.94	10.67	[illegible]	21.33	26.71	32.10	37.50	42.89
1.3	-	-	4.59	5.96	8.99	12.01	[illegible]	24.21	30.33	36.47	42.62	48.78
1.4	-	-	5.14	6.68	10.10	13.48	20.32	27.21	34.11	41.05	47.99	54.95
1.5	-	-	-	7.41	11.20	15.00	22.64	30.34	38.06	45.82	53.59	61.40
1.6	-	-	-	8.18	12.40	16.58	25.05	33.59	42.17	50.79	59.42	68.10
1.7	-	-	-	8.97	13.60	18.21	27.55	36.96	46.43	55.95	65.48	75.08
1.8	-	-	-	9.79	14.80	19.90	30.13	40.45	50.83	61.29	71.75	82.29
1.9	-	-	-	10.62	16.10	21.63	32.79	44.05	55.39	66.81	78.24	89.76
2.0	-	-	-	11.49	17.40	23.43	35.53	47.77	60.08	72.50	84.94	97.48
2.1				12.37	18.80	25.27	38.35	51.59	64.92	78.37	91.84	105.40
2.2	-	-	-	13.28	20.20	27.15	41.25	55.52	69.90	84.41	98.94	113.60
2.3	-	-	-	14.21	21.60	29.09	44.22	59.56	75.01	90.61	106.20	122.00
2.4	-	-	-	15.16	23.00	31.09	47.27	63.69	80.25	96.97	113.70	130.70
2.5	-	-	-	16.13	24.60	33.11	50.39	67.93	85.62	103.50	121.40	139.50

Note: Approximate values of flow for heads other than those shown may be found by direct interpolation in the table.

From: *Groundwater and Wells*, Second Edition, 1986.

6.0 DOCUMENTATION

Information required by this procedure will be documented on the discharge measurement notes shown in Figure 4-4. These notes can be found in the Surface Water Data Collection Form (Form SW.1A). The form is found in, *Surface Water Data Collection Activities* (RMRS 1994). Data required by this procedure includes flow measurement device calibration information and field flow measurement data.